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## A CELL-INSPIRED MODEL OF CONFIGURATION

### ABSTRACT

The purpose of this paper is two-fold. It first presents a biosemiotic comprehension of artefact making, on the basis that both design and life are processes of construction. It then presents a computer model to substantiate the position and approach to form making. The basic premise is that life is, at heart, artefact making and that the process of creation is fundamentally semiotic. All things are coupled, paired or exist relationally and the key to assembly is communication and signification; from the perspective of both agency (in life processes) and the agent of fabrication (in artificial construction). The approach argued for in this paper is thus an effort to capitalise on the artefact making processes understood as intrinsic to the generation of shape and form in nature.

The computer model presented is applied as a means to generate diagrams representing conceptual illustrations of architectural layouts. A bottom-up approach to the organisation of architectural-space is thus presented, which offers a fresh outlook on the approach to the automatic generation of architectural layouts. Artificial creatures, modelled on Eukaryotic cells, are used as components with which to generate configurations articulating patterns of habitation. These components represent discrete activities, perceived to be the basic building block of spatial configuration in architecture, which self-organise and aggregate to form a cohesive body.



INTRODUCTION

This paper presents a bottom-up approach to organising architectural-space, which offers a fresh outlook on the automatic generation of architectural layouts. Artificial creatures, modelled on Eukaryotic cells, are used as components with which to generate configurations articulating patterns of habitation. These components represent discrete activities. Activity is perceived to be the basic building block of spatial configuration in architecture. Attributes, pertaining to input and outputs, establish activities as occurring in chains of action; affected by that which has preceded and affecting that which is to transpire. Topology, describing space as a set of points, accounts for this chain depicting connectivity and the convening of points to describe form. Activities can have equivalence in terms of location, occurrence and so forth, and may thus have varying degrees of correspondence. Mereology, a theory of parthood relations, takes regions (as opposed to points) as the ontological primitive. Coupling topology and mereology (known as mereotopology) defines a more concrete analysis of spatial conditions (Cohn and Hazarika 2001), and provides a clearer basis for interpreting, and therefore establishing the relation between one activity and another. Being artificial creatures these activity-components have the capacity to interact with their environment and each other and self-organise to form aggregations. The model demonstrates an ecological approach to designing in a manner that unites computational design with biological and semiotic theory. The theoretical basis of the model is first outlined, and then the computer model is presented and described.

THEORETICAL PREMISE

Taking the basic unit of existence to be the organism-in-its-environment (the living-cell being the nascent form), which is coupled to the world through its capacity to sense, and thus interpret its surroundings, 'human-space' may be comprehended (from an evolutionary perspective) by extending the issue downwards to the pattern recognition and control processes of simpler organisms; on the premise that the mechanisms we see at play in single-cell organisms lead to higher and higher degrees of sign processing in humans. The spatiality of an organism is affected through its capacity to sense, which underpins perception and capacity to engage with the world. This ability (stemming from our cells) is ambient and distributed, and from this perspective space is 'lived'. Effected through the ability to feel or perceive and affect the environment, space is a (habitual) state of fluidity and perpetual readjustment articulated through an organism's activity and interaction. Having the capacity to distinguish self from nonself, a cell is, thus, a model of the ontology of 'self' (see Weber 2009 and Hoffmeyer 2008). The spatiality of an organism and its engagement with its surroundings may thus be extrapolated on the basis of cell (inter)action. This assessment is based on the following four principles:

1 As Charles Peirce held, 'the universe is perfused with signs', and that a sign is fundamentally a difference which holds some meaning for an interpreter perceiving said difference in some context (Peirce 1894).

- 2 Gregory Bateson's (1972) notion that 'a difference is a difference that makes a difference' and that on this premise what we refer to as 'information' is the plethora of differences that exist which an interpreter acts on.
- 3 A system has identity, which its components share. A difference is therefore 'observed' by a component as something which is not an aspect of its identity, which it thus responds to (Luhmann 2006).
- 4 Space is social because it unfolds through interaction (Massey 2005) and, as a social product, is reflexive. It is both produced and productive (Lefebvre 1995). "Space is neither a 'subject' nor an 'object' but rather a social reality – that is to say, a set of relations and forms" (Lefebvre 1995, p. 116).

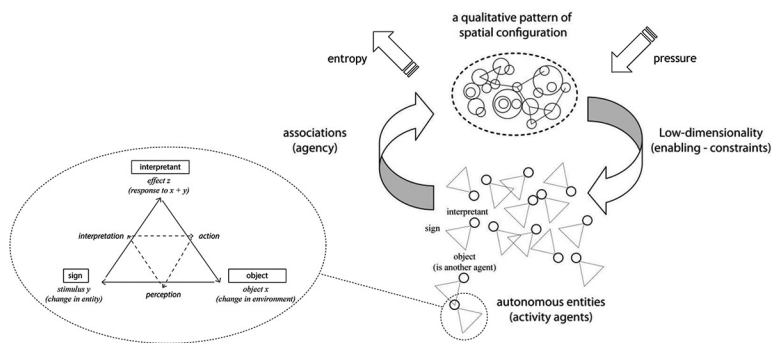
These four principles define the basis of a computational methodology for generating architectural spatial formations (outlined below), which is presented here as an approach to generating 2-dimensional configurations of activity-space. The paper thus presents an alternative approach to generating architectural layouts in manner conveying semiotic exchange between self and non-self; which is the core of organismic being-in-the-world, and thus a method articulating inhabitation.

A CELL-INSPIRED METHODOLOGY OF CONFIGURATION

In the model presented the collective (social) behaviour of distributed (swarm) systems is utilised to capitalise on their constructive (i.e., nest building) and configurational activities (i.e., agglomeration of slime moulds and food foraging in ants). The distributed pattern forming and constructive tendencies of these phenomena are adapted to the problem of configuring architectural space. Figure 1 depicts the exemplary of the computer model to be presented, illustrating how configuration arises from a disorganised to an organised arrangement. It serves two purposes. On one side it is an abstract illustration of an autonomous system composed of various constituents; on the other it illustrates a (computing) methodology of configuration; it describes a qualitative-semiotic conception of spatial configuration incorporating three levels of assembly. At the base-level, discrete components with semiotic competence come into relation with one another; forming associations between one another. These semiotic-components detect what is out there and, distinguishing a difference, respond relative to a corresponding (stored) value, thereby acting on the difference detected. As these associations form, they constrain the behaviour of individual components to define couplings between associates which coalesce; forming compositions which reflect their form of association mereotopologically, i.e., they are connected or have some form of overlap. These associations steer interaction between couplings to form assemblages which, at the mid-level, define patterns of association. In other words level one is the defining of relations between discrete components, which come together to form parts at the second level. These couplings are steered by new or unrealised associations which subsequently form new couplings at the third level to form a body of parts. This ascension could of course consist of manifold levels in which component parts form parts of parts, which in their

own right form bodies, which constitute meta-bodies, and so on. Figure 1 may therefore be redrawn as a series of moments articulating the development of form, instead of, as it does, the three step-changes outlined:

- 1 Discrete components (at the base level) couple according to their relevance (conditioned by their association and state of being). Note the two entities shown to be coming into relation, emphasised by the inset illustrating the emergence of overt behaviour.
- 2 The spatial articulation of these couplings in which the components coalesce to form parts, which
- 3 Converge to form a body of parts; articulated by the dashed line to emphasise the formation of a whole.



**Figure 1**  
A proto-model system of configuration.

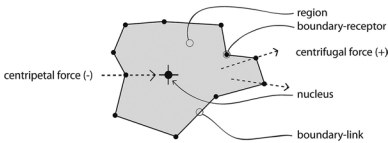
The computer model is agent-based. The basic component is an actant (see Note 1), which represents a region of space specific to a discrete activity. An actant is a semiotic entity composed of discrete semiotic components, modelled on the cell: the basic unit of all known living organisms which has the capacity to distinguish self from nonself. The living cell is thus a model of the ontology of 'self'. The notion of the semiotic-self is central to the conception of this model, emphasised by Hoffmeyer (2008) as extant through exchanges between internal and external domains. Orientation is effected through a semiotic interface, and by which the disparity on either side of the divide is managed. Reiterating Barry Smith's (1997) account of 'oriented' boundaries, Hoffmeyer refers to the living cell's 'self' (inner domain) as existing "only in so far as that which is inside contains an intentionality towards, or reference to, that which is outside" (Hoffmeyer 2008: 174): an ascending condition replicated at the scale of an organism responding to effects impinging on its territory. An actant distinguishes self from not-self, and is oriented via its ability to identify differences in its environment.

The model is composed of several actants (which are swarm-like entities) that coalesce according to their relations to generate an aggregation; and articulate a pattern of

activity. The actants thus act like a slime mould, whereby the individual spores agglomerate when starving, to form a single body. The model is thus conceived to be (or to generate) a 'body of swarms'. The notion is predicated on Jesper Hoffmeyer's (1994) paper *The Swarming Body* (see Note 2). He makes an analogy, describing the body of an organism as a hierarchy of overlapping swarms (of swarms) constituting an assemblage of cohabitation. "At all levels these swarms are engaged in distributed problem solving based on an infinitely complicated web of semiotic interaction patterns" (Hoffmeyer 1994, p. 938). Another theoretical contribution informing this model is Barry Smith and Achille Varzi's (2002) hypothesis of organism-environment relations. They present a general theory of niche dynamics to explain how population interactions are projected into the spatial dimension. A general hypothesis is thus proposed, for creating causally relevant spatial regions that generate spatial formation in a cell-like manner.

### AN ACTANT

The basic component of the model is an actant, an artificial creature whose composition is depicted in Figure 2. The boundary is a mutable entity whose configuration affects the region, which represents a discrete space-of-activity. The boundary consists of nodes (boundary-receptors) which are affected by differences in the environment, that can effect a centrifugal or centripetal force affecting the actant's motion. An actant moves through the collective activity of its boundary-receptors, which move whilst emitting and responding to differences they detect. I will from here on in refer to such differences as 'semione', to denote any kind of sign-vehicle an actant is capable of emitting or receiving. An actant deposits a unique semione, thereby identifying itself. Each actant has identity, which its components share; represented by colour and an index to which other actants refer. A difference may, therefore, be 'observed' by a boundary-receptor as something which is not an aspect of its actant's identity, which it thus responds to by positioning itself according to its association with the actant detected. The actants configure themselves according to those actants they have an association (or dissociation) with by responding to their semione. The nucleus represents the organism (performing 'x' activity), and the boundary delimits the region pertaining to the activity the actant represents. Configuration arises in the model as a result of boundary conformation, determined by the way the boundary-receptors respond to differences detected; acting in accordance with the associations their actant has with other actants.



**Figure 2**  
An actant is an autonomous entity with sensorial capacity.

An actant moves via the collective actions of its boundary-receptors, which (if not affected by semione) move relative to their distance from the nucleus and nearest neighbouring boundary-receptor. The former is a simple attract-repel mechanism (if too close to the nucleus step away from it, and if too distant step towards it); the latter a repel mechanism from the closest boundary-receptor of the same actant. This results in a wandering-like behaviour in which the collective moves in a unified manner, reminiscent of the movement of amoebae. An actant wanders in this way for a period until, if no other actants are sensed, one of its boundary-receptors extends outwards



to become a 'hunter'. Having done so, the hunting boundary-receptor will move away from the nucleus, extending the actant's search space to seek associate actants beyond its immediate vicinity. If another boundary-receptor is perceived, the hunter will position itself according to the relation between the two actants: see right-hand image of Figure 3. Otherwise the hunter switches back to its boundary-receptor state and settles back. This hunting action is analogous to pseudopodia (the cellular extensions) of eukaryotic cells when feeding. The propulsion of the hunter-extension can affect the course of the actant's wandering. If no associate is sensed after another period of wandering the hunting behaviour is repeated. The autonomy and sensorial capacity of an actant means that its form is changeable. An actant is a mutable figure affected by the conditions in which it is situated and affected by its composition, motion (and thus time), and its relations to other actants.

BOUNDARY CONDITIONS

William Mitchell (1998) describes architecture as 'an art of distinctions'—between solid and void, internal and external, and so on—determining boundaries between categories around which differences are recognised, and thereby manipulated. The act of distinguishing is a process of construction that brings the world into focus; transformed from an amorphous muddle into something that can be read because aspects are composed by the individual into distinct parts which are organised in some particular way. Smith and Varzi (2000) differentiate two types of boundary. Bona-fide boundaries are literal, relating to concrete physical objects. Fiat boundaries (such as between one country and another, or an arm and a hand) are a matter of perception. Fiat objects are not specific, but shaped by the state of the observer, space, and time. Objects such as a table, the moon, Ireland, and Ozzy Osbourne are bona fide, but the distinction between their parts may be fiat; such as between Ozzy's head and his body, and the boundary between the Irish Republic and Northern Ireland. "One important motor for the drawing of ephemeral fiat boundaries is perception, which as we know from our experience of Seurat paintings has the function of articulating reality in terms of sharp boundaries even when such boundaries are not genuinely present in the autonomous physical world" (Smith and Varzi 2000, p. 6). Whilst architectural endeavour clearly strives to account for the nuances of the individual and peoples activity the focus of concern is typically with (bona-fide) built form, to which fiat conditions are fitted. Designing a building is typically dependent on the past: i.e., what has been done before and experience. In an effort to break the cycle and to enable the propensities of a scenario to prompt formation, the author seeks to mediate the reciprocity between bona-fide and fiat bounds. The focus of this model is the primary condition of generating fiat bounds, through which (with further work) bona-fide bounds may be established: on the basis that the bona-fide is not necessarily a literal comprehension of the fiat.

An actant represents a discrete activity and thus what its boundary articulates is fiat; expressing the bounds of an activity to articulate patterns of behaviour, through the

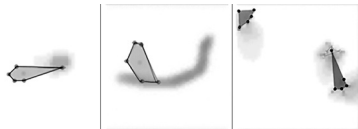


Figure 3  
Actants responding to semione; (left) to a semione source, (center) following a semione trail; and (right) engaging with an associate actant.

actants aggregation. As the interface between variant domains (through which communication is effected and difference is maintained), the boundary is conceived a form of agent affected by the multiplicity of interactions between actants with their own timing, spacing, goals, means and ends. The configuration of the actants results from their boundary conformation to context represented tangibly and effected via the sensibility of their boundary-receptors. The presence of semione is particular to each actant, according to meaning and proximity. Semione distinguished by a boundary-receptor is an object of focus causing the actant to be oriented.

ACTANT-ACTANT INTERACTION

An activity may have various attributes which may form an input or output. The associational possibilities between one activity and another are numerous. El-Attar (1997) defines architectural space as "an allocated structure of composed parts, enclosing a group of users and their artefacts, the purpose of which is to provide a suitable environment for the behaviours and structures that are enclosed." The composition is purposeful, which he specifies "is to provide a desired set of behaviours through the structures that compose it, such that these behaviours meet the environmental, social and cultural needs of a group of users performing a known set of activities" (El-Attar 1997, p. 109, p. 121). The information potential of an activity (see Figure 4) provides a basis for distinguishing the associations between actants (representing discrete activities), enabled through a distributed, self-organising process to generate arrangements depicting architectural-space.

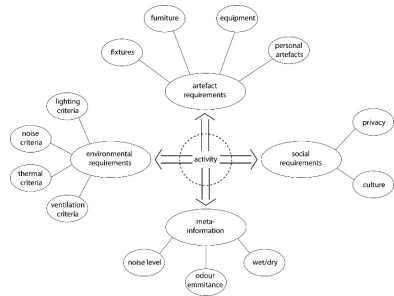


Figure 4  
Information potential the archetypal activity (redrawn from El-Attar 1997).

An activity in isolation is meaningless. Activities are defined functionally as a component, whose function is participation in the production (or articulation) of other activities. Even though an activity may have no specific or physical relation with another, its existence is contingent on its attributes. An activity is thus governed through association to corresponding activities: that an activity is defined by another activity, by which it is effected and another activity which it affects. Perceived as a chain, an activity has an input and output; goal-directed in an indirect and recursive way, in the sense that something (A) affects something else (B) in a manner which supports 'B' to be or behave in the manner of 'B'. In this way an activity is defined by a causal chain of connections. Imagining an organism's pattern of inhabitation composed of discrete activity-niches we now look at how these discrete niches may combine to form aggregations as a result of their relations and how these translate spatially.

The interaction between one actant and another relates to behaviours transpiring from the various ways one organism may respond to another encroaching on its territory. The encounter may achieve their coupling or hostility and may either result in collision (in which case their territories will conjoin) or dispute (whereby incompatibility will lead to conflict and distancing between them). Otherwise they may be nonchalant to one another, in which case their territories may overlap. Withstanding dispute and

nonchalance their meeting leads to deformation of their territories. These potential forms of interaction establish the basis of the actants agency; describing the manner in which they may interact and how this interaction may be projected spatially. Figure 5 illustrates how these interactions may be projected spatially, to define a series of relation-potentials between actants that are subsumptive. The relation-potentials distinguish the spatial-property of actant relation as a scale, not of dimension, but as a gradient or degree of consolidation.

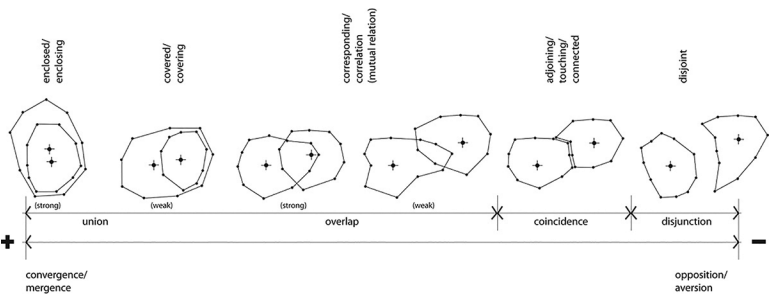


Figure 5  
Relation potentials.

Defined as a scale, these relation-potentials are measurable and define forces which are transferred to the actants as a means by which to (self) organise according to their associations. The effect of one activity on another may be positive, negative or indifferent, resulting in forces for conjunction (positive), disjunction (negative) or negation (indifferent). The form of association and behaviour of an actant is determined by its capacity to sense and distinguish semione. The semione has meaning for an actant, being a signal, which it responds to. If the relation is positive it will follow the semione 'uphill', towards the source of production (Figure 3). If the relation is negative it will follow the semione 'downhill', moving away from the source. This attract-repel behaviour is reminiscent of predator-prey relations. Having detected an associate actant, the actant will position itself according to the relation between it and the other, which it does by way of its boundary-receptors positioning. Accordingly, an actant is equipped with the capacity to 'smell' and 'touch'. The capacity to smell is enabled through the ability to distinguish contrasting forms and levels of semione. The capacity to touch is enabled through a 'field-of-view' which a boundary-receptor uses to determine proximity to another boundary-receptor, to settle such that its actant seeks to adjoin. Overlapping is realised through boundary-receptors determining whether they reside within the confines of another actant or not. If a boundary-receptor is located within another actant's region the two actants overlap. The degree of overlap may then be determined by the number of boundary-receptors an actant has in another's region.

Figure 6 illustrates several actants settled in different configurations satisfying the same associations: 'a' adjoins 'b', 'c' intersects 'b', 'd' adjoins 'c', 'e' intersects 'd' and 'f'

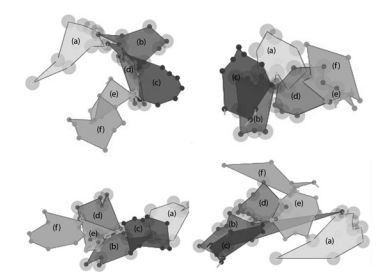


Figure 6  
Model results.

intersects 'e'. While the resulting configuration satisfies the individual actant's associations, the arising configuration is different each time, because history is a significant aspect of the model. The actants' 'behaviour' is tensive, because an actant that has settled (once it has satisfied its associations) may become unsettled by another actant's actions. This can cause the overall configuration to unravel, because if a settled actant's associate is unsettled it is then caused to move; spoiling the settled actant's state of harmony, causing them both to re-seek their state of cohesion. This is good, because the final configuration rests on the harmony of all actants realising their individual associations. Configuration in the model is aggregative, occurring through the individual actant's conformation, determined by the behaviour of the population. The resulting configuration is an expression of the actants associations, and is a description not a definitive solution.

DISCUSSION

Human activity has developed in-line with social and technological change and our changing patterns of activity affect the development of built form, revealing a pattern of progress since humankind first progressed from congregating around the camp-fire. Strangely enough architects "tend to consider space as an abstract concept and not a behavioural phenomenon, and yet paradoxically assume that behaviour will follow their predictions" (Lawson 2001, p. 200). By taking a distributed approach this gap may come to be bridged. The spatial salience of an organism is an effect of its distributed cognition, and this is constructive (Gardner 2011). On the basis that design is a constructive activity (Glanville 2006), the distributed cognition of an archetypal organism may be transferred to designing on the basis that 'to design, is to configure'—meaning to arrange elements or parts in a particular way so as to satisfy some need—and this is akin to the development and survival of an organism-in-its-environment.

Whilst architectural endeavour clearly strives to account for the nuances of the activity of individuals and groups, the focus of concern is typically (bona-fide) built form. The fiat is typically fitted to the bona-fide on the basis of what one knows, or what has been done before. There is no problem with this—people are adaptable—only it tends to articulate the moderate and follow standardisation. Hillier et al. express the morphology of social relations encapsulated in built forms to reveal the structure of the fiat operating from the bona-fide. It is the reciprocity between the bona-fide and fiat bounds that the author seeks to mediate, and with this model generate fiat bounds to (with further work) establish bona-fide bounds. The methodology (see Figure 1) evokes configuration a process of agency between tangible and perceived. The model presented takes a distributed, as opposed to an authoritative, approach, which transpires as a result of the collective capacities of the actant (i.e. the components constituting it) and the actant population. Additionally, in the model presented, the authoritative self that Mitchell describes distinguishing between differences is parsed to the collective, constituting the (archetypal) organism-in-its-environment.



The actants' behaviour (see Figure 3) and the results (see Figure 6) illustrate configurations resulting from autonomous interacting bodies, which are themselves composed of autonomous components that can distinguish self from not-self. The boundary-receptors exemplify the basis of Figure 1, since it is through these that the relations between actants are formed. However, while there is sign-action semiosis is not present in the model: see inset of Figure 1. Configuration emerges through the actants response to semione but the actants themselves and their associations are defined. As it is they come together to articulate their discrete associations (Level 2) to form a cohesive body (Level 3). The distinction behind Level 1 raises a key issue with the model. The model exemplifies a self-organising process and the arising configuration is (computationally) emergent, but the actants have pre-defined components and the associations between are planned. Establishing a means for the relations between the actants to emerge, as opposed to being calculated, would be a significant benefit because, currently, the model simply produces configurations articulating programmed inputs: a typical issue with computational and pre-determined systems design. For any relation to emerge semiosis would be required to occur in the model, to drive activity not articulated by an operator, and thereby the materialisation of the actants extemporaneous spatial formation.

CONCLUSION

This paper presents a biosemiotic approach to architectural design. The methodology presented is predicated on semiosic interaction being the basis of organismic interaction-in-the-world and how it transfers to designing on the basis that artefact making is intrinsic to life. The methodology (see Figure 1) thus seeks to define an approach to using computation as a means to designing that embraces the semiosic basis of life as an engine through which to drive architectural spatial formation. The computer model, as it stands, is a rhetorical device demonstrating the theoretical standing. It is presented here as a means to generate activity patterns that may then be used as a basis for developing architectural layouts. However, the application is subjective, and the model may be developed in various ways towards different architectural applications at different scales. The author is currently focused on developing the model as a diagramming tool to aid the development of conceptual architectural layouts, and for creating causally relevant spatial regions that generate spatial formation in a cell-like manner, which may then be extended three-dimensionally to volumes.

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NOTES

1. A term borrowed from Bruno Latour (1996) to refer to an autonomous entity-in-its-environment.
2. The idea for this model preceded my review of Hoffmeyer’s paper, but the notion therein presented consummated the idea.

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